Renewable and Sustainable Energy Reviews 28 (2013) 400–409

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The scenario of greenhouse gases reduction in Malaysia

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ARTICLE INFO

Article history:
Received 1 March 2013
Received in revised form
30 July 2013
Accepted 11 August 2013
Available online 30 August 2013

Keywords:
Greenhouse gases (GHGs)
Global warming
Dioxide carbon
Methane
End-use sectors
Renewable and sustainable energy (RSE)

ABSTRACT

Today, an unprecedented increase in global temperature is attributed to the rising rate of greenhouse gases (GHGs) emissions due to human activities. Fossil fuel combustion in end-use sectors releases the majority part of GHGs. Global warming and climate changes occur due to the GHGs production and CO_2 forms around 72% of total GHGs. Necessity of investigation in GHGs reduction in different countries is more highlighted when statistics illustrate that CO_2 emission has raised 1.6 times in recent decades. Although, Malaysia is not listed in Annex I countries in Kyoto Protocol (KP), this developing country has taken part actively in GHG reduction under the KP programs. Rising rate of GHGs generation in Malaysia due to conspicuous progressive in industry and increasing rate of the population have convinced the government to invest in GHGs reduction through different programs. Fuel consumption optimization, alternative fuel utilization and palm trees plantation are the main strategies have taken into account by Malaysian government. This paper is an overview of the main sources of GHGs in Malaysia and aims to review the preventive proceedings that should be taken by the Malaysian government.

Contents

1. Introduction

Climate change has become one of the main concerns of humanity in recent century [1]. The negative effects of GHGs emission on people health are unavoidable fact [2]. The most abundant GHGs in the atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) [3]. The heat radiation from the surface of the earth can be trapped by GHGs in the atmosphere and global warming is the main consequence of GHGs effect. Fig. 1 depicts the GHGs effect schematically [4,5].

The atmospheric lifetime of the gas has been defined as the period of time that a kilogram of that gas remains in the atmosphere before removing by chemical reaction. For instance the life time of CH_4 and CO_2 has been estimated around 12 and 200 years, respectively. So many activities have been performed by different countries to control the rising rate of GHGs production in the world. United Nations Framework Convention on Climate Change (UNFCC) is the nonbinding protocol goaled at atmospheric GHGs reduction which more than 150 countries agreed on that [6]. The Kyoto Protocol (KP) was adopted by the participant countries in UNFCC in December 1997. The content of KP which is an

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http://dx.doi.org/10.1016/j.rser.2013.08.045

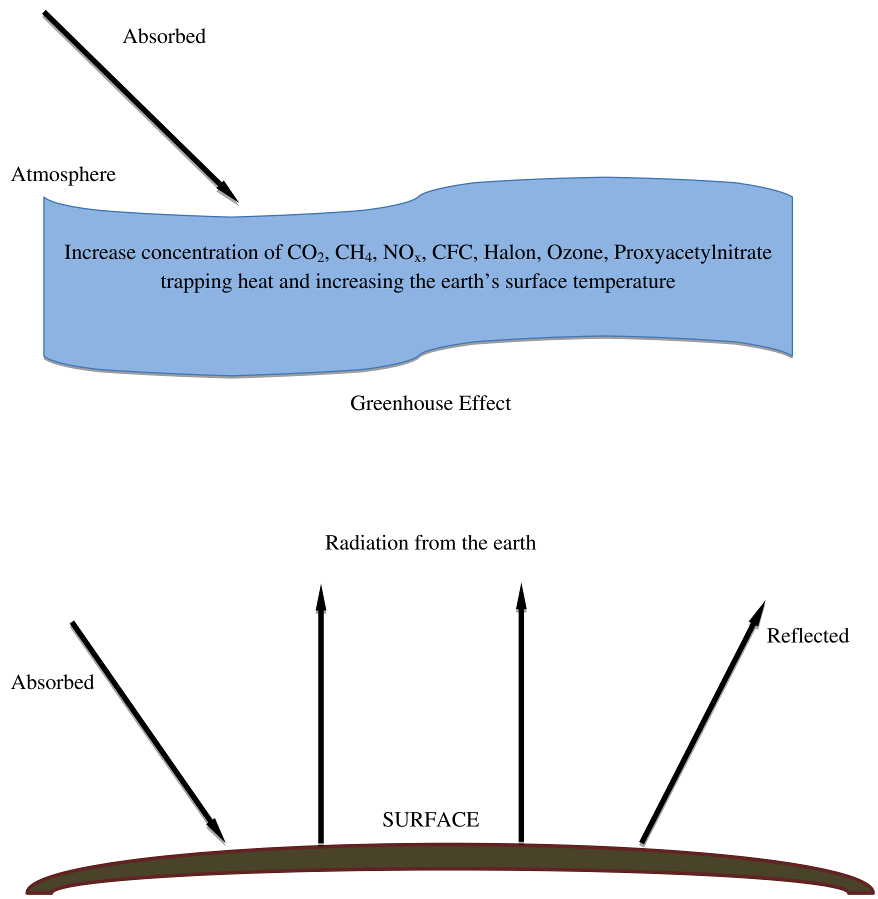

Fig. 1. Schematic of GHGs effect [4,5].

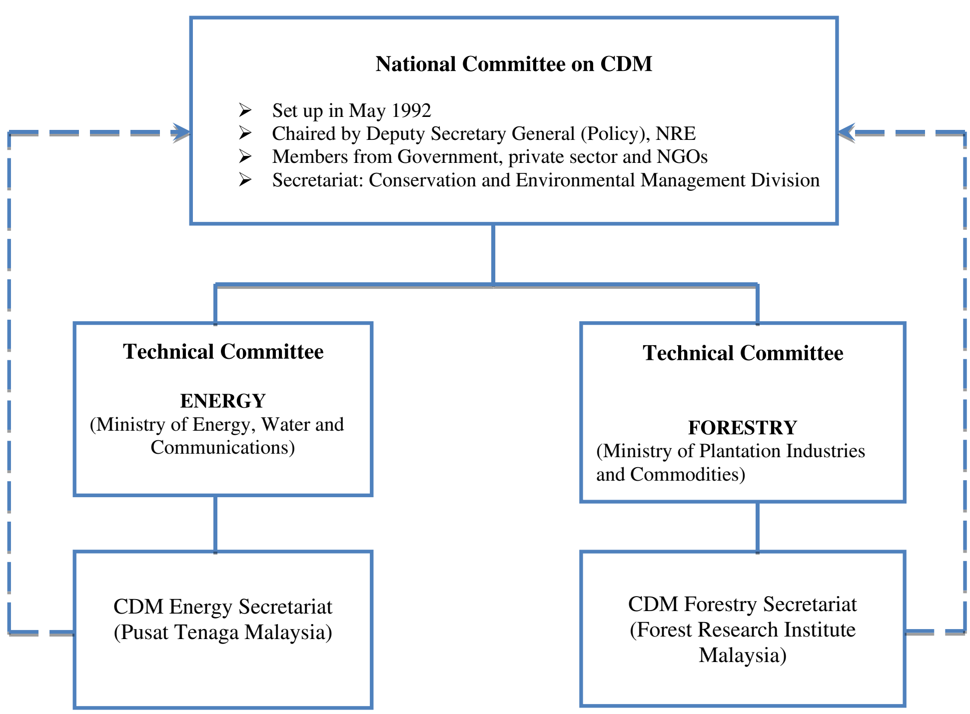

Fig. 2. The framework of CDM institution in Malaysia [10].

international treaty to combat climate change by urgent global GHGs reduction is similar to UNFCC; however the countries have been listed in Annex I and non-Annex I. The developed countries which have been listed in Annex I have been bound to reduce the rate of GHGs emission to the specific amounts according to the related timetables. In contrary, the non-Annex I countries have not urged in GHGs reduction. The developing country Malaysia which has been listed in non-Annex I countries ratified the KP at

Table 1
A Summary of climate, health, economy and emission related to black carbon, ozone and sulphates [12].

	Main sources	Toxicology	Epidemiology	Climate	Ecosystems	Control
Sulphate particles	Power plants, industry and transport	Pure sulphate not shown to be toxic at concentrations encountered in the environment	Could have larger relative effects than undifferentiated	Generally cooling with some difference by location and complexity when in mixture	Acid precipitation is of little uncertainty, but wide difference in effect by location	Control of sulphur dioxide has some, but not large interaction with other types of control
Black carbon particles	Household solid fuels, industrial coal, forest, grassland burning, diesel from incomplete combustion	Pure EC is not very toxic in human and animal studies at environmental levels	Measured as EC might have not large effects than undifferentiated fine particles, but results are not stable when other pollutants are included in models	Major uncertainties, but high warming potential that is complicated by location, short life and mixture with other aerosols	Melting and warming effects if it falls on ice or snow, particularly in Arctic and Himalayas; not yet well understood	Control also reduce organic carbon emissions which are generally cooling, net climate effect thus varies depending on source OC/BC ratio
Ozone tropospheric	Precursors, methane and MMVOCs with combustion and non-combustion sources and NO_x mainly from combustion	Oxidative stress and inflammation pathways established for toxicity of pure ozone at or near environmental concentrations	Might have mortality effects that are independent of small particles; evidence is more extensive for short-term exposure, but results suggest much larger effects from long-term exposure	Warming potential well established, but total effect shared across precursor emissions in complex ways	Adversely affects agriculture and ecosystems; might reduce carbon storage	Complex atmospheric chemistry determines importance of VOGs vs NO_x control locally

September 2002 [7,8]. Although Malaysia does not have any obligation for emission reduction, Clean Development Mechanism (CDM) offered by KP for Annex I countries has been created a window for non-Annex I countries like Malaysia to participate in GHG reduction voluntary in sustainable manner. CDM has significant benefits for Malaysia environmentally and economically such as GHGs reduction and alternative energy development. According to GHGs producers world ranking published by Yale University, Malaysia was 26th country among 149 countries in GHGs production by final score 84 [9]. Currently, the ministry of Natural Resources and Environment (NRE) is responsible for CDM in Malaysia and some projects such as forestry projects, renewable and sustainable energy (RSE) projects and energy efficiency projects have been defined as the priorities of CDM. Fig. 2 illustrates the frame work of National Committee on CDM in Malaysia [10].

GHGs production and global warming phenomena not only impact on environment and economy but also have conspicuous effects on the human health. Agriculture, forestry and tourism industry in Malaysia could be affected by more pollutant production in this country. Moreover, heart stroke, respiratory and cardiovascular problems, respiratory and cardiovascular problems and the risks of death from dehydration are the most important effects of GHGs on human health. Basically, the effects of GHGs on human health have been referred to black carbon, ozone and sulphates. Heart diseases, lung damage and asthma attack can be intensified by ground level ozone or so-call bad ozone [11]. Table 1 demonstrates a summary of climate, health, economy and emission related to aforementioned pollutant [12].

Energy consumption is the base of progress in the industry and economic developments. However, more pollution formation is the main consequence of more fuel utilization [13,14]. Indeed, raw materials can be transferred from one product to another, but this conversion can release anthropogenic emissions of CO_2, CH_4, N_2O, halocarbons (HFCs) and sulphur hexafluoride (SF_6) from industrial production processes. These emissions are not directly generated from the energy consumed during the process. In Malaysia, emission from fuel combustion, fugitive emissions from oil and gas system, burning of biomass fuel and fugitive emissions from coal mining and palm oil mills are categorized in emission from energy sectors. Also, emissions from industrial process are generated from metal production, consumption of mineral products and production of chemical products [15].

2. CO_2 emission

Carbon dioxide (CO_2) formation in fossil fuel combustion and its climate impaction has become the most important issues politically and scientifically. The rate of CO_2 generation has been increased rapidly during last 50 years [16]. Around 30 billion tons CO_2 release to the atmosphere through human activity annually [17]. Although the preventive role of CO_2 for the earth from space frozen balls is unavoidable, global warming and rising rate of droughts, storms and floods are the main results of much CO_2 concentration. Statistics show that the rate of CO_2 constitution has increased 30% globally and the temperature has increased 0.3–0.6 °C recently [18]. Consequently, the levels of the sea has raised 10–20 cm during last century due to the melting of the polar ice cap and glaciers, which increase the level of water in the oceans and the sea [19]. Carbon dioxide is the most important gas within the context of greenhouse gas emissions. CO_2 is the most abundant gases in the atmosphere and has a high calorific power. Moreover, it was easily generated by human activities, essentially by fossil fuels and wood burning. Related to that, CO_2 may consider as reference gas for greenhouse and other gases are stated in CO_2

units. CO_2 emissions are produced from fertilizer production, farm fieldwork, manufacture and supply of machinery, grain drying and electricity consumption. Over 3912 million tonnes of CO_2 equivalents in 2010 was produced from two principal sources which are oil and gas-fired power stations generating electricity, and road transportation, which includes the use of cars and collective passenger road transport, as well as freight transport. The other main contributors of emissions are coming from fuel combustion in manufacturing industries. Furthermore, energy-intensive activity such as the manufacture of iron and steel or chemicals and households in the form of fuel combustion for domestic heating are mentioned as the main sources of GHGs emission. Fig. 3 depicts the historical data of global CO_2 emission from 2000 to 2013 and anticipates the rate of CO_2 formation until 2030 by different end-use sectors [20].

2.1. CO_2 emission in Malaysia

In Malaysia, transportation system, electricity generation, industrial sectors and residual have been mentioned as the main contributors of CO_2 emission. According to statistics from Asian Pacific Energy Center (APEC), the outlook period for CO_2 emission from energy consumers in Malaysia is projected to grow about 4.2% annually reaching 414 million tone of dioxide carbon in 2030. Apart from fuel combustion, agricultural activities and waste

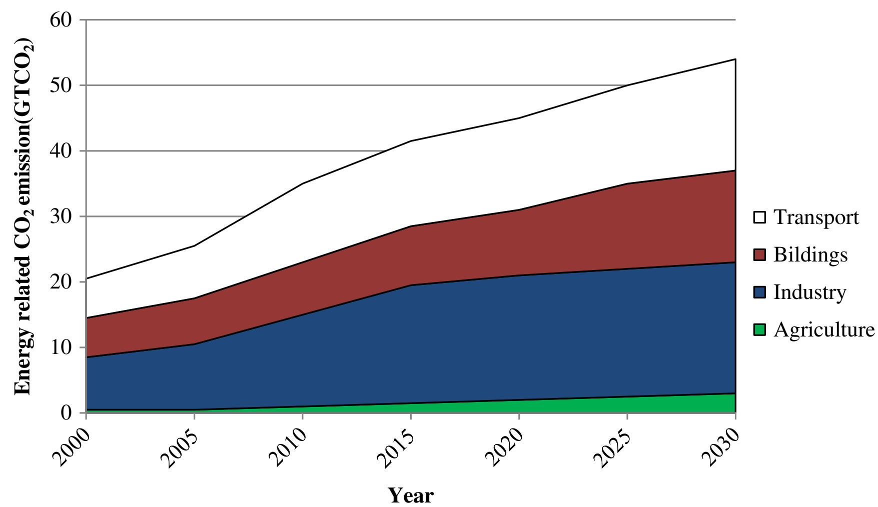

Fig. 3. The rate of global CO_2 emission by end-use sectors from 2000 to 2030 [20].

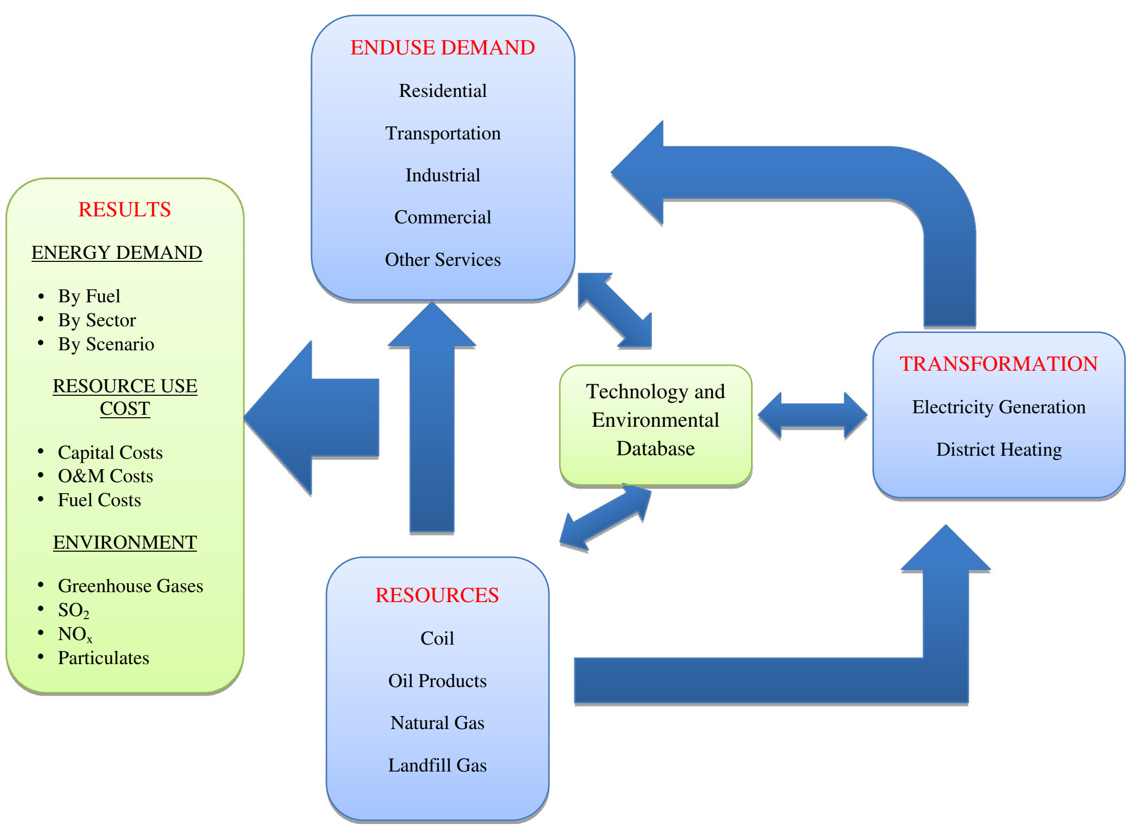

Fig. 4. The schematic of LEAP model [22].

materials includes disposal and water treatment are the other resources of GHGs generation in Malaysia. Based on Long-range Energy Alternatives Planning system (LEAP), the rate of CO_2 emission from fossil fuel-based sectors for the period of 2000 to 2020 can be modeled [21]. The structure of LEAP model which consist of energy demand, energy conversion, transmission, distribution, and end-use has been shown in Fig. 4 schematically [22].

Invoking to LEAP model and the related formulas [23] the trend of energy demand and CO_2 emission in Malaysia from 2000 to 2020 has been plotted in Figs. 5 and 6, respectively [17].

Some data such as the rate of population growth, the level of the global wealth and the rate of energy demand have been applied to anticipate the rising rate of CO_2 production. The population growth has been assumed 2.1% from 2010 to 2020 in Malaysia [24].

2.2. CO_2 removal process in Malaysia

To reduce the rate of CO_2 formation from fossil-fuel power plants some applicable strategies should be taken into account.

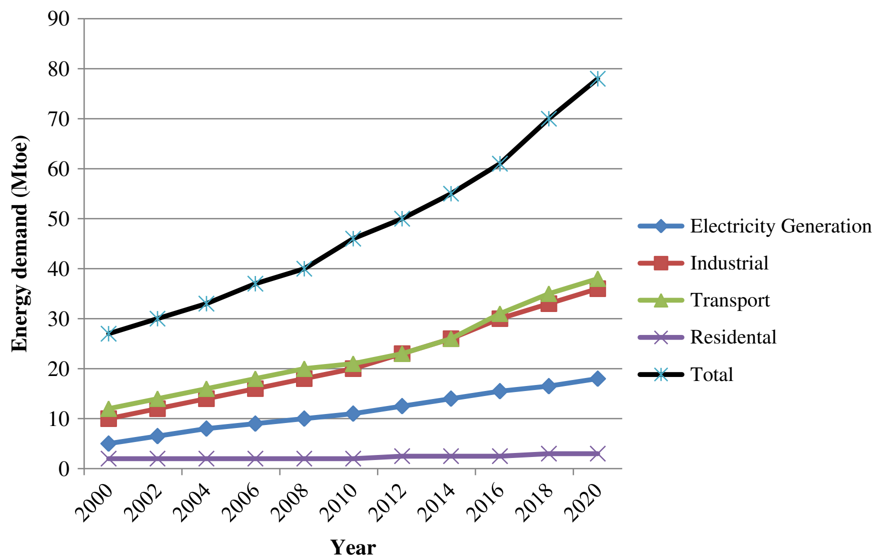

Fig. 5. Energy demand for different sectors in Malaysia [17].

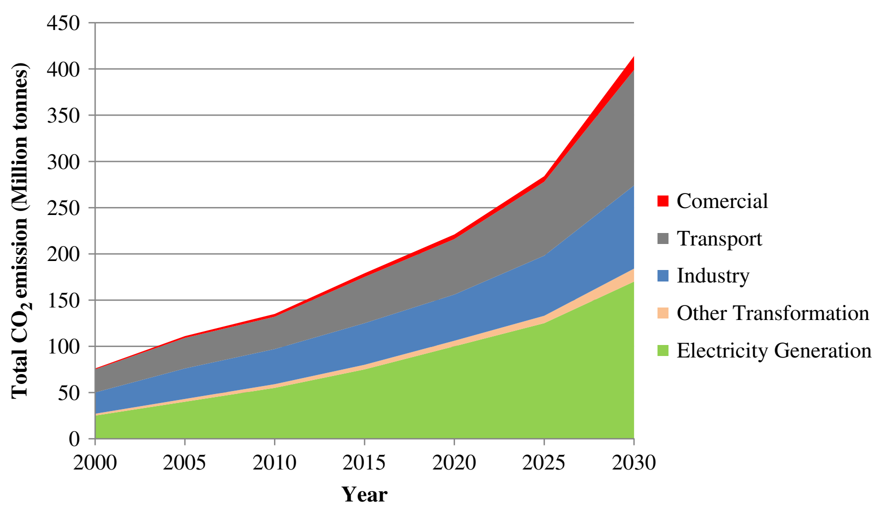

Fig. 6. CO_2 emission from different resources in Malaysia [17].

Table 2
Strategies planned by NRE for GHG reduction regarding to the forest [10].

Objective	Sub-objective	Solution	Action
Reduce GHG emissions from forest	Reduce deforestation (decrease depletion of carbon stocks)	Reduce forest fire	Improve forest fire management
		Reduce conversion to other land uses	Develop alternative income opportunities
		Reduce logging	Decrease net log production volume
	Increase reforestation (carbon sequestration)	Accelerate natural forest regeneration	Decrease waste in log production
		Accelerate forest regeneration artificially	Improve land management
			Plant trees

CO_2 capturing method and employing carbon sequestration, switching the fuel and application of alternative fuel especially biofuel and biogas and increasing the efficiency of the power plants are the best methods to approach low CO_2 emission in Malaysia [25]. Theoretical calculations confirm that by implementation of some strategies like raising thermostat set point of a refrigerators and air conditions and observing energy efficiency standards, the rate of GHGs can be declined in Malaysian household applications drastically [26]. In Malaysia, palm plantation and permanent forest have played crucial role in CO_2 removing. The rate of CO_2 removal was reported 167 Mt and 82 Mt by forest and palm plantation respectively and they were still the main CO_2 removers for Malaysia up to now. This removal trend seems to continue in future because Malaysian government has adopted some strategies to increase the palm plantation in the future. Some strategies for GHGs reduction regarding to the forestation planned by NRE in Malaysia have been summarized in Table 2 [10].

3. CH_4 emission in Malaysia

CH_4 emission has been emitted from anthropogenic and natural sources. Around 70% of worldwide methane emission is related to anthropogenic sources. The concentration of CH_4 $_{in}$ atmosphere has been tripled during last 150 years [27]. Some sources such as municipal solid waste (MSW) [28], landfills and old waste deposits [29,30], coal mining [31], anaerobic digestions [32], cattle ranching [33], rising main sewers [34], agricultural products [35], the processing and drilling of oil and gas [36] and rice paddies [37] have been mentioned as the main sources of CH_4 constitution. Moreover, animal husbandry is one of the most important sources of CH_4 in the world [38,39]. It has been stipulated that around 15% of global methane generation is related to CH_4 emission from ruminants [40]. Also, around 18% of GHG emissions have been referred to the animal husbandry [41]. In this case about 84% animal CH_4 generation is related to buffaloes and cattle′s enteric [42]. The government of Malaysia has some strategies to develop the agricultural livestock such as cows, buffaloes and goats under the National Meat Policy in order to increase the Malaysia′s self-sufficiency in meat products. Therefore, the rate of CH_4 production by livestock resources increases and some appropriate strategies should be taken into account in this case. Base on emission factors for enteric fermentation and manure management offered by IPCC in Table 3, the rate of CH_4 emission by different livestock in Malaysia has been provided in Table 4 [43].

The type of treatment or storage facility, the ambient climate and the composition of the manure are the most important factors effect on the quantity of CH_4 emission from manure. Enteric fermentation and manure storage at dairy industry can be excellent sources of CH_4 generation. Although the rate of CH_4 concentration in the atmosphere is relatively low, its calorific power is 21 times greater than CO_2. The CH_4 emissions would also related to the treatment technology used for waste water cleaning. The appropriate strategies in waste water recirculation can increase the possibility of biogas generation as a RSE fuel from these waste materials. Also, some executive implementation such as composting of MSW, landfill capping, aerobic landfilling and biogas capturing released from landfills are effective factors for CH_4 reduction in landfill waste management [44].

Table 3
Emission factors for enteric fermentation and manure management [43].

Livestock	Enteric fermentation	Emission management
Cattle-diary	68.0	31.00
Others	47.0	1.00
Buffalo	55.0	2.00
Sheep	5.00	0.20
Goats	5.00	.022
Pigs	1.00	7.00
Horses	180	2.19
Poultry	0.02	0.02

Table 4
Total CH_4 emissions by different livestock in Malaysia [43].

Livestock	Total CH_4 emission (Gg) (1980)	Total CH_4 emission (Gg) (2008)
Cattle	45.61	65.24
Buffalo	18.55	8.52
Sheep	0.63	0.32
Goats	1.79	1.49
Horses	0.10	0.14
Pigs	14.70	14.93
Poultry	2.18	8.17

4. Energy mixed strategy in Malaysia

Around 53% augmentation in world energy demand has been prognosticated by the International Energy Agency by the year 2030. Fossil fuel by around 88% utilization is the most common sources of energy demand which is provided by oil, coal and natural by around 35%, 29% and 24% respectively. Nuclear energy with 5.5% and hydropower by 6.4% supply the small part of required world energy. As fossil fuels resources are transitory and their consumption is one of the main sources of GHGs production, the role of RSE resources has been highlighted in recent decades [45]. The emissions released from fossil fuel combustion can endanger the ecosystems; therefore the environmental concerns related to fossil fuel consumption have increased. Indeed, the rate of energy lost and GHGs generation in energy conversion process from primary energy (e.g. crude oil, natural gas, uranium) into the secondary energy (e.g. electricity, petroleum) is considerable [46]. Today, around 11% of energy demand of the world has been supplied by renewable energy resources [47]. The most important kinds of RSE and the scenario of their contribution in global energy supply up to 2040 have been summarized in Table 5 [48].

In order to achieve low pollutant formation, energy saving and redaction petroleum dependency targets, Malaysian government adopted the Five-fuel Diversification Strategy in 1999. In this strategy natural gas, hydro, renewable energy, coal and petroleum have been mentioned as the main source of energy demand in Malaysia. Biomass can be one of the best sources of renewable energy in Malaysia due to abundance of natural resources and jungles [13]. Recently, natural gas has been utilized as the main source of energy in Malaysia. Malaysia by around 1000 million cubic feet per day is the largest natural gas reservoir in South East Asia and 12th largest in the world. This valuable opportunity has been taken into account by Malaysian government to increase natural gas application in transportation system. Indeed, some infrastructures such as instruction for periodic technical inspection of the vehicle, retiring old vehicles, road inspection, research and development to biofuel car promotion have been implemented by the government [17]. In the other hand, the fuel diversification strategy was implemented by Malaysian government due to fluctuations in crude oil prices. In this case it has been tried to decline the role of crude oil in energy mix in Malaysia. Therefore, the production and utilization of biodiesel has been developed vastly in Malaysia. It has been stipulated that the rate of GHGs production can be reduced dramatically by palm oil-based biodiesel utilization in Malaysian transportation system. Moreover, according to the policies 5.5% of total electricity generation in Malaysia should be based on biofuel utilization by the

Table 5
The contribution of renewable and sustainable energy in global energy supply by 2040 [48].

	2001	2010	2020	2030	2040
Total consumption (million tons oil equivalent)	10038	10549	11425	12352	13310
Biomass	1080	1313	1791	2483	3271
Large hydro	22.7	266	309	341	358
Geothermal	43.2	86	186	333	493
Small hydro	9.5	19	49	106	189
Wind	4.7	44	266	542	688
Solar thermal	4.1	15	66	244	480
Photovoltaic	0.1	2	24	221	784
Solar thermal electricity	0.1	0.4	3	16	68
Marine (tidal/wave/ocean)	0.05	0.1	0.4	3	20
Total RES	1365.5	1745.2	2964.4	4289	6351
Renewable energy source contribution (%)	13.6	16.6	23.6	34.7	47.7

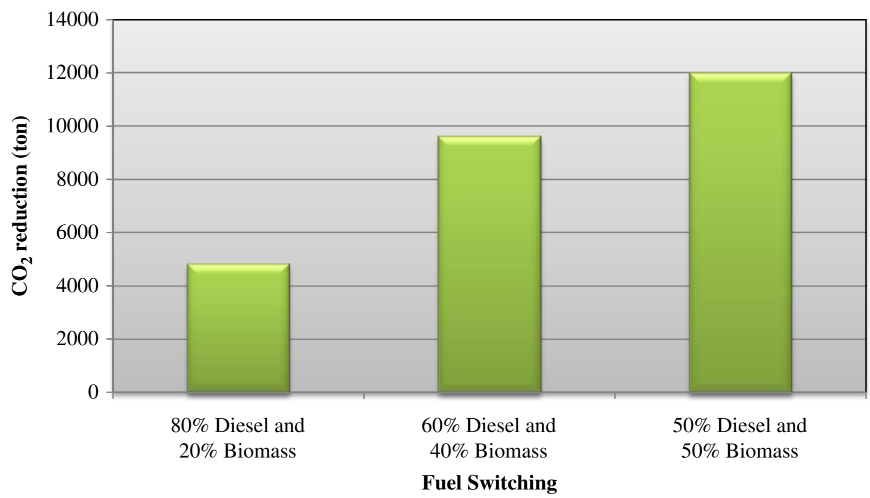

Fig. 7. CO_2 reduction in industrial boiler fueled by various biodiesel blends [58].

year 2015 [49]. Hydropower by negligible GHGs generation could be the valuable source of energy in Malaysia. The potential of electricity generation from hydropower in Malaysia has been foreseen around 29,000 MW [50]. However, this excellent opportunity has not been developed properly yet and only around 2091 MW power has been generated in this country [46]. Beside hydropower, solar energy and wind energy can be the most promising sustainable energy resources and they have great potential to generate clean energy in the world [51,52]. Malaysia has favorable climate circumstances for solar and wind energy development. The daily average of solar irradiations in Malaysia is relatively high due to the abundant sunshine in various seasons and it has been recorded from 4.21 kW/m^2 to 5.56 kW/m^2 annually [53]. Currently, the application of this environmentally friendly source of energy has been limited to domestic level and around 10,000 domestic solar energy units have been reported throughout Malaysia. Totally, despite all of the efforts for renewable energy promotion, the maximum potential of these sustainable energies has not been achieved yet. To attain sustainability in fuel mix strategy some factors such as raising a wider application of renewable energy, increasing the rate of efficiency in energy production, conversion and utilization should be observed.

5. GHGs reduction in Malaysian industries

5.1. Palm oil industry

Today fossil fuel depletion and more toxic emission formation from combustion of fossil fuel have become the main concerns of energy and environmental societies [54]. The environmental dilemma problems such as climate change, receding of glaciers, increasing the sea level, GHGs effects and lack of biodiversity have been emerged due to lack of appropriate strategy to control the pollutant formation in transportation systems and industrial sectors [55]. Therefore, RSE resources like agricultural products, animal waste, municipal solid wastes and wastewater effluent have been developed to cope with these problems [56]. Also, biodiesel, biomethanol, bioethanol and biohydrogen as the main biomass products have been applied vastly in energy generation. Huge amounts of biofuel resources, fluctuation in fossil fuel prices and environmentally friendly characteristics of biofuel combustion process have convinced the governments of tropical countries to invest in development of biofuel industry [57,58]. It has been proven that the application of biodiesel blends mitigates the rate of CO_2 formation in industrial boilers dramatically [59]. As it has been shown in Fig. 7, the rate of CO_2 reduction in different industrial boilers fueled by biodiesel is related to the fuel combination [58].

To have a correct judgment about the effects of biodiesel on climate, total well to wheel GHGs effects include production, distribution and utilization should be considered. Fig. 8 depicts the different steps of traditional diesel and biodiesel cycle to illustrate the GHGs generation in the various stages.

Palm oil by around 35.5% total annual production has been known as the biggest vegetable oil in the world [60]. Appropriate equatorial climate in Malaysia is the main cause of palm trees cultivation in this country and the great potential of energy generation from palm oil is the base of palm oil mills development [61]. Palm oil-based biodiesel has shown more GHGs saving

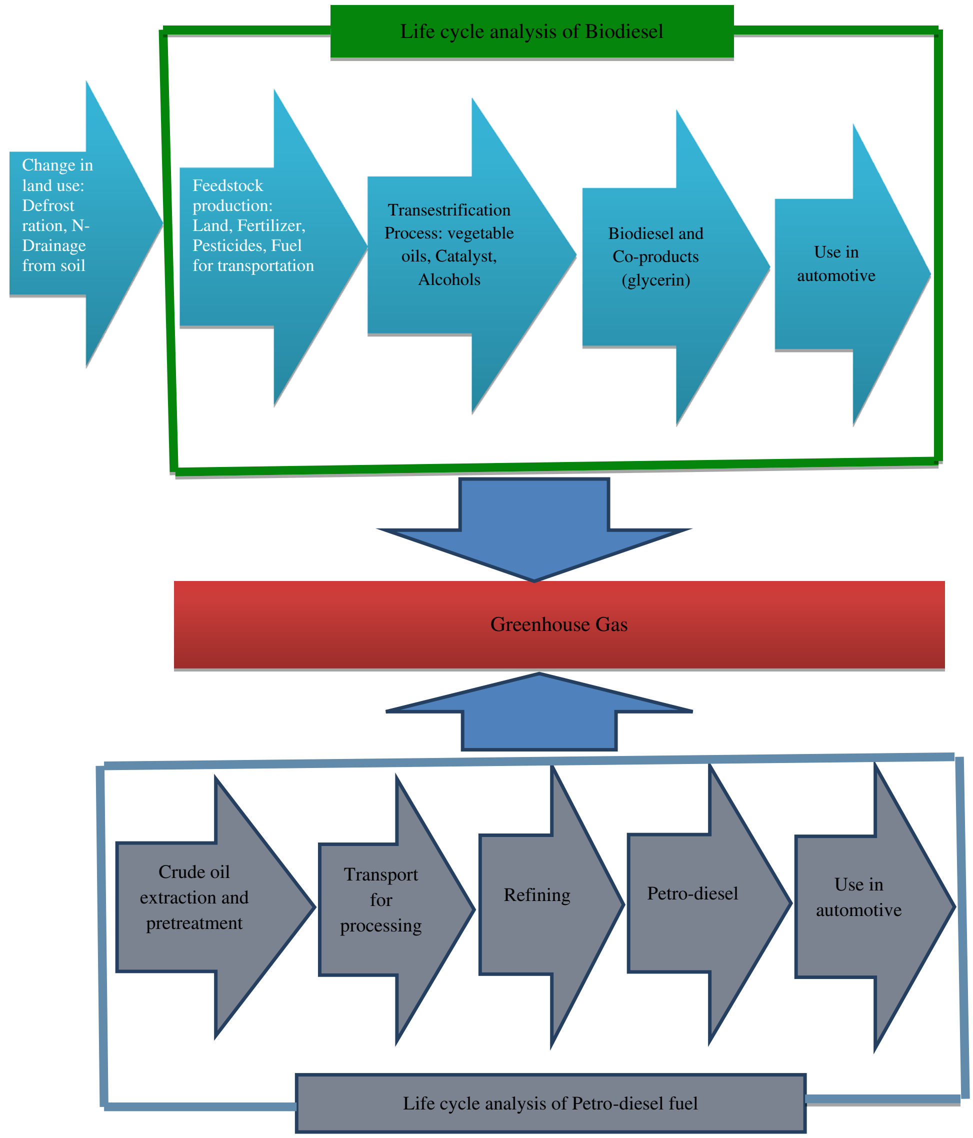

Fig. 8. GHGs generation in different steps of traditional diesel and biodiesel cycle [58].

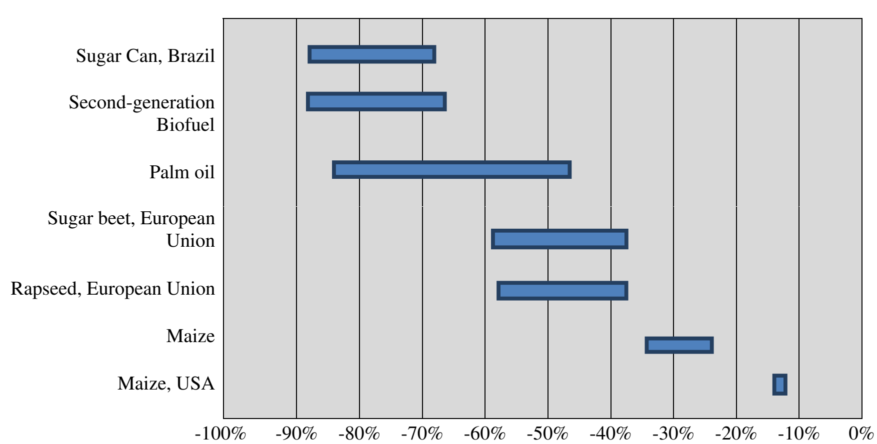

Fig. 9. GHGs emission reduction of various biofuels relative to fossil fuels [62].

compared to the other biodiesel feedstock as it has been illustrated in Fig. 9 [62].

However, CH_4 generation from anaerobic digestion mechanism of palm oil mill effluent (POME) is the most important challenge in production process of palm oil factories [63]. Furthermore, the rate of methane generation from POME increases conspicuously when solid residues like empty fruit bunches (EFB) are added to the POME [60]. Indeed, the number of palm oil factories has increased sharply due to the global interest to palm oil-based biofuel. In 1960, the number of palm oil mills were reported 10 factories in

Malaysia, however 410 palm oil mills were recorded in Malaysia by the year 2008 [61]. The rate of POME released from palm oil production process is around 2.5–3 t/1 t crude palm oil production [64]. This contaminated POME which is generated from the first step of biodiesel production can endanger the environment [65]. POME can treat the atmosphere by huge amounts of CO_2 and CH_4 production [56]. Carbon Emission Reduction (CER) strategy can be obtained by applying the closed anaerobic digestion systems according to CDM instructions [66].

5.2. Mineral and chemical production

Total amount of CO_2 released to the atmosphere from Malaysian industrial sectors was reported 13,690 Gg in which 9776 Gg from the mineral industries (such as cement production, lime production, limestone and dolomite use) 1118 Gg from the chemical industry (like ammonia production, nitric acid production, carbide production) and 2797 Gg from the iron and steel industry. Moreover, 4.28 Gg of CH_4 from the petrochemical industry (the process of coke, methanol, styrene carbon black and ethylene production) and 0.66 Gg of the N_2O from nitric acid production were generated from industrial processes in Malaysia. Also, the amount of HFC and SF_6 were measured 0.11 Gg and 0.00026 Gg, respectively [15]. In Malaysia, cement production is the largest GHGs emitter industry due to the contaminated manufacturing process and utilization of fossil fuel in the combustion process. CO_2 is generated from clinker production in cement making. Clinker as an intermediate production is made when limestone is heated to produce lime and substantial amount of CO_2 is also generated during this reaction. The final amount of generated CO_2 depends on the type of cement being made. Lime is the other important products in Malaysia applied in cement production process, steel making, pulp and paper manufacturing and construction. Quicklime type is the most common production in Malaysia. Many lime producers in Malaysia are still using traditional port kilns which are able to produce between 30 t and 70 t of quicklime per unit. CO_2 emission from lime production in Malaysia is measured based on the common process in the production of quicklime [15]. Application of low emission combustion technologies [67], using alternative fuel [16], utilization of high performance filters, cyclone and electrostatic precipitator in cement and lime industries could be effective for pollutant reduction in Malaysian industries.

6. Conclusion

Energy supply, GHGs generation from different energy resources and climate change plays crucial role in the global policy planning. Various ecosystems can be jeopardized by increasing rate of pollutant emissions in combustion processes, therefore the environmental concerns related to fossil fuel application in transportation system and industrial sectors have augmented. In order to control the increasing rate of GHGs production and global warming phenomena, some global protocols like UNFCC and KP have been adapted. Huge amount of pollutant formation is one of the main consequences of the significant progress in industry and the raising rate of population in Malaysia. Therefore, the Malaysian government has been convicted to participate in GHGs removal programs actively. Increasing the efficiency of power plants and alternative fuel application in power generation, RSE employment, CO_2 capturing and carbon sequestration, biogas capturing from MSW, landfills and anaerobic digestions and biodiesel utilization in transportation and industrial sectors are the main preventive strategies for GHGs augmentation rate in Malaysia. From overall review, Malaysia has great potential in RSE utilization and especially biodiesel production due to its numerous palm trees and jungles. In environmental aspect, palm trees plantation is one of the best strategies to CO_2 removal. Moreover, the utilization of palm oil-based biodiesel as an environmentally friendly fuel with low pollutant formation in combustion process should be developed in Malaysia.

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